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FLAVOR QUALITY AND STABILITY OF POTATO FLAKES: EFFECTS OF ANTIOXIDANT TREATMENTS

INTRODUCTION

PREVIOUS STUDIES of the oxidative deterioration of potato flakes have demonstrated that product storage stability is dependent on raw material quality and on peeling, cooking, and drying conditions (Sapers et al., 1973, 1974). Dehydrated mashed potatoes are usually stabilized against oxidation by the addition of antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) at levels prescribed by the Food and Drug Administration (Code of Federal Regulations, 1973). These antioxidants may be added as components of emulsions containing other ingredients or as alcoholic sprays. One of the objectives of the current study was to determine the effects of different methods of addition on antioxidant retention and product stability.

The polyunsaturated fatty acids of potato, from which oxidative off-flavors arise, are found principally in the relatively polar glycolipid and phospholipid fractions of the potato fat (Ben-Abdelkader, 1968). The total lipids represent only about 0.7% of the dry weight of the potato (Mondy et al., 1963). Efforts to stabilize the lipids in this system must contend with the problem of dispersing fat soluble antioxidants in a largely aqueous medium. Pratt (1965) suggested that certain naturally occurring flavones and substituted cinnamic acids might have potential value as antioxidants in such low fat aqueous foods. The antioxidant activity of quercetin and other polyhydroxy flavones may be due to their ability to complex metal ions, or more likely, to act as free radical acceptors (Pratt and Watts, 1964). Quercetin and caffeic acid are considered to be relatively nontoxic compounds (Stecher, 1968; Griffith et al., 1955), although they are not currently approved as food additives in the United States. Sato et al. (1972) used caffeic acid to prevent quality deterioration in sake; Radaeva and Tyukavkina (1972) employed quercetin as an antioxidant in dry milk products. These and related compounds may be responsible for the antioxidant activity ascribed to plant extracts used to preserve dehydrated vegetables (Nestle's Products Limited, 1967). A second objective of this study was to determine the efficacy of quercetin and caffeic acid as antioxidants in potato flakes.

EXPERIMENTAL

Raw material and process

Potato flakes were prepared from Norchip tubers, harvested in North Dakota in the Fall of 1972 and stored for 3 months at 7°C followed by 1 month at 18°C prior to processing. The raw material had a specific gravity of 1.092 and contained approximately 0.024% fructose, 0.028% glucose and 0.020% sucrose (fresh weight basis).

Processing was carried out in the pilot plant of the Red River Valley Potato Research Center, East Grand Forks, Minn. The potatoes were abrasion peeled, subdivided, dipped 5–10 sec in 1% $NaHSO_3$ solution, precooked for 20 min at 71–77°C, cooled for 20 min at 10°C, steam cooked for 30 min at 100°C and mashed in a Hobart Mixer. An ingredient emulsion containing 20g mono- and diglycerides (Durkee EM 200 E), 15g sodium acid pyrophosphate, and 2.50g $NaHSO_3$ in 725 ml H_2O was added to each 22.7 kg (50 lb) batch of potatoes during mashing.

Antioxidants were added to 22.7 kg portions of mashed potatoes in the Hobart Mixer as follows:

1. Control–1.5 ml Tenox 4 (Eastman; 20% BHA and 20% BHT in corn oil) added in the ingredient emulsion.
2. Tenox 4 spray–1.5 ml Tenox 4 applied as a spray using a Freon-propelled aerosol sprayer.
3. Tenox 5–1.2 ml Tenox 5 (Eastman; 25% BHA and 25% BHT in ethyl alcohol) diluted to 100 ml with ethyl alcohol and applied with the aerosol sprayer.
4. Quercetin–0.274g quercetin (Baker) dissolved in 100 ml ethyl alcohol and applied with the aerosol sprayer.
5. Caffeic acid–0.164g caffeic acid (Baker) dissolved in 100 ml ethyl alcohol and applied with the aerosol sprayer.
6. Tenox 5 + quercetin–1.2 ml Tenox 5 and 0.274g quercetin dis- in 100 ml ethyl alcohol and applied with the aerosol sprayer.
7. Tenox 5 + caffeic acid–1.2 ml Tenox 5 and 0.164g caffeic acid dissolved in 100 ml ethyl alcohol and applied with the aerosol sprayer.

Drying was carried out using a single drum drier operating at a drum speed of 2.2 rpm, as described previously (Sapers et al., 1974). The finished flakes were packaged in polyethylene-lined fiber drums and shipped to the Eastern Regional Research Center in Philadelphia for further study.

Storage and evaluation

Samples were air- and nitrogen-packed in No. 303 and No. 10 cans and were stored at –18° and 23°C.

Initially, flakes were analyzed for moisture, equilibrium relative humidity, and sulfur dioxide; these data are summarized in Table 1. In addition, analyses were carried out for BHA, BHT and quercetin initially and after 12 months of storage. Quercetin was determined in alcoholic extracts prepared as follows: 10g potato flakes were reconstituted with 50 ml boiling water. The resulting paste was cooled and extracted with 100 ml absolute ethanol in three successive portions. Alcoholic extracts were combined, filtered through a Buchner funnel having a coarse porosity fritted disc, concentrated to 25 ml on a steam bath, cooled and extracted with 100 ml diethyl ether in three successive portions. The ether extracts were combined, concentrated to 10–15 ml on a steam bath, cooled and diluted to 100 ml with absolute alcohol. A 10-ml aliquot was analyzed by the spectrophotometric method of Naghski et al. (1951).

Table 1–Moisture and sulfur dioxide in potato flakes

Antioxidant treatment	Moisture content (%)	Equilibrium R.H. (%)	SO_2 (ppm)
Tenox 4 control	6.04	20.1	350
Tenox 4 spray	6.44	21.5	446
Tenox 5	7.17	27.8	352
Quercetin	7.02	26.3	280
Caffeic acid	6.54	23.5	207
Tenox 5 + quercetin	7.16	28.6	400
Tenox 5 + caffeic acid	6.04	19.3	341

[1] A Center operated cooperatively by the USDA North Central Region, ARS; the Minnesota Agricultural Experiment Station; the North Dakota Agricultural Experiment Station; and the Red River Valley Potato Growers Association.

Gas chromatographic (GC) determinations of volatile oxidation products in potato flake headspace vapor (lower boiling components) and in volatile concentrates prepared by steam distillation (higher boiling components) were performed using procedures described by Sapers et al. (1972). GC analyses were carried out in duplicate initially and at intervals during storage. Quantitative GC data were calculated as the ratios of individual oxidation product peak areas to the peak area of an internal standard (ethyl butyrate) which was added to each sample prior to analysis. These data were expressed more concisely as the sums of the peak area ratios for the major volatile oxidation products found in potato flakes in current and previous studies as described by Sapers et al. (1973).

Sensory evaluations were performed by a 15-member trained taste panel at the same intervals as the GC determinations. Flake samples (including a hidden standard) were compared with a standard, the nitrogen-packed frozen Tenox 4 control, using an eight point rating scale ranging from "much better than standard" (8) to "extreme off-flavor" (1). Results were expressed as mean flavor scores. The significance of differences reported by the panel was determined using Duncan's multiple range test.

All procedures and analytical methods used in this investigation have been described previously (Sapers et al., 1973, 1974) except as otherwise specified.

RESULTS & DISCUSSION

Antioxidant retention

Levels of addition of BHA and BHT in this study corresponded to concentrations of 55–60 ppm in the dehydrated potato flake products. As can be seen in Table 2, the actual antioxidant concentrations, determined by analysis, were substantially lower than the added levels, representing a recovery of only 15–35%. Initial antioxidant concentrations were lower and varied more from product to product with flakes containing Tenox 5 than with the Tenox 4 flakes. Initial levels of BHT were lower than corresponding BHA levels in the Tenox 5 samples.

These initial antioxidant losses are typical for the potato flake process and presumably result from vaporization and steam distillation during the addition of antioxidants to the hot mash and during drum drying (Ogg, 1960). Differences between Tenox 4 and Tenox 5 may be due to the volatility of the solvent (corn oil vs ethanol) rather than to the method of addition; the application of Tenox 4 as an emulsion or by spraying resulted in similar antioxidant levels. BHA and BHT concentrations obtained with Tenox 4 in the current study are comparable to those found previously (Sapers et al., 1973, 1974) and fall within FDA limits.

Variations in antioxidant concentrations within products, determined by analyses of replicate (6–8) flake samples representing several cans, were not related to the different antioxidant treatments described herein. Coefficients of variation ranged from 3–6% for BHA and from 7–12% with BHT; this difference is probably due to the method of analysis rather than to the uniformity of the flakes.

The method of antioxidant addition did not affect the retention of BHA and BHT in air-packed potato flakes stored for 1 yr at 23°C. Storage losses of BHA were negligible under these conditions. However, small losses of BHT did occur during storage, probably as a consequence of degradation rather than volatility since the samples were packaged in hermetically sealed cans.

Quercetin concentrations in the flakes containing quercetin alone, and quercetin in combination with Tenox 5 were found to be 39 and 41 ppm, respectively, representing a recovery of approximately 70%. After 12 months storage in air at 23°C, these samples contained 38 and 36 ppm quercetin, respectively.

Table 2—Retention of BHA and BHT in potato flakes stored in air at 23°C

	Concentration (ppm)					
	BHA		BHT		Retention (%)	
Antioxidant treatment	Initial[a]	12 Months	Initial[a]	12 Months	BHA	BHT
Tenox 4 control	20.3	20.4	20.8	16.8	100	81
Tenox 4 spray	19.5	19.5	18.6	14.5	100	78
Tenox 5	13.4	13.6	12.5	10.7	101	86
Tenox 5 + quercetin	14.5	13.5	10.5	7.8	93	74
Tenox 5 + caffeic acid	11.4	10.4	8.4	6.2	91	74

[a] Theoretical concentration = 55–60 ppm

Table 3—Effect of antioxidant treatments on the stability of potato flakes stored in air at 23°C

Antioxidant treatment	Storage time (months)	Mean flavor score	Sum of major volatile oxidation products	
			Headspace vapor	Volatile conc
Tenox 4 control	0	4.7	0.085	3.71
	6	4.1	0.122	5.85
	12	3.8	0.138	7.94
Tenox 4 spray	0	4.8	0.027	1.16
	6	3.4[a]	0.066	3.57
	12	3.1[b]	0.104	5.72
Tenox 5	0	4.8	0.052	2.62
	6	4.1	0.090	4.92
	12	3.2	0.132	9.54

[a] Significantly different from Tenox 5 at 0.05
[b] Significantly different from control at 0.05

Effect of antioxidant treatment on storage stability

Sensory and gas chromatographic data summarized in Table 3 indicate that the method of antioxidant addition had a relatively small effect on the storage stability of air-packed potato flakes containing BHA and BHT. Mean flavor scores for the three treatments were similar initially. The Tenox 4 spray treatment received significantly lower flavor scores than were obtained with the Tenox 5 treatment after 6 months and the control containing emulsified Tenox 4 after 12 months storage.

Levels of major volatile oxidation products were determined in the headspace vapor above reconstituted flakes and in the volatile concentrates prepared by distillation. Initially, oxidation product levels were lowest in flakes containing Tenox 4, applied by spraying, and were highest in the control. During storage the extent of oxidation increased in all samples. After 6 months, the initial order was unchanged, oxidation product levels increasing by about the same amount with all three treatments. After 12 months storage, oxidation product levels were highest in the Tenox 5 sample and lowest with the Tenox 4 spray treatment. However, oxidation product levels increased less in the control than in the other samples during the 6–12 months storage period. The lack of agreement between the GC and sensory data for the Tenox 4 spray sample may have been due to the presence of some unknown factor other than oxidation (i.e., a contaminant introduced during processing or canning) which influenced product flavor.

Neither the mean flavor scores nor the volatile oxidation product levels appear to be correlated with initial or final concentrations of BHA and BHT, within the narrow limits obtained in this study. There is some indication that increases in oxidation product levels during the 6–12 months storage peri-

Table 4—Effects of quercetin and caffeic acid on the stability of potato flakes stored in air at 23°C

Antioxidant treatment	Storage time (months)	Mean flavor score	Sum of major volatile oxidation products: Headspace vapor	Sum of major volatile oxidation products: Volatile conc
Quercetin	0	4.8	0.059	2.35
	6	3.3	0.206	12.78
	12	3.1	0.204	17.56
Caffeic acid	0	5.0	0.054	2.39
	6	3.9	0.232	11.72
	12	2.9[a]	0.251	18.83
Tenox 5 + quercetin	0	4.7	0.020	1.12
	6	4.4[b,c]	0.051	4.02
	12	3.4	0.079	6.98
Tenox 5 + caffeic acid	0	4.9	0.024	0.88
	6	4.0	0.094	5.11
	12	3.7	0.123	10.46

[a] Significantly different from control at 0.05
[b] Significantly different from quercetin at 0.05
[c] Significantly different from Tenox 5 at 0.05

od are inversely related to antioxidant concentration. Although differences between samples are small, the control treatment is recommended over the other methods of antioxidant addition since this procedure results in higher and more uniform antioxidant levels than were obtained with Tenox 5, a higher flavor score after 12 months and a smaller increase in volatile oxidation product level during storage.

Effects of quercetin and caffeic acid on storage stability

Stability data for potato flakes containing quercetin, caffeic acid and combinations of these compounds with Tenox 5 are summarized in Table 4. Initially all samples were satisfactory with respect to mean flavor scores and levels of major volatile oxidation products. During storage, flakes containing quercetin and caffeic acid alone were substantially less stable than the samples containing Tenox 4 and Tenox 5 (Table 3).

Quercetin and caffeic acid were added to potato flakes at concentrations of 5×10^{-5} M, comparable to levels found by Pratt and Watts (1964) to be effective in retarding the oxidation of roast beef slices. The poor performance of quercetin and caffeic acid in potato flakes may be due to their limited mobility in the dehydrated state or to the use of an inadequate level of addition. Much higher concentrations probably could not be used because of the low solubility, yellow color and bitter flavor of these compounds (Stecher, 1968; Seidell, 1941).

Potato flakes containing caffeic acid in combination with Tenox 5 were generally similar in storage stability to flakes containing only Tenox 5 and to the control (Table 3). Increases in levels of volatile oxidation products were higher in the former sample, possibly because of the lower concentrations of BHA and BHT obtained with this treatment. In the absence of any evidence for significant antioxidant activity or synergism, no advantage can be seen for the addition of caffeic acid to potato flakes.

Flakes containing quercetin in combination with Tenox 5 received a significantly higher flavor score than the flakes containing Tenox 5 alone after 6 months storage and had lower levels of volatile oxidation products than the Tenox 5 or control treatments throughout the study. Increases in volatile oxidation products during storage were lower in the quercetin plus Tenox 5 combination than with the Tenox 5 treatment and were comparable to the control, even though the latter flakes contained substantially higher levels of BHA and BHT.

The results show sufficient promise to warrant confirmation and further study. Higher concentrations of quercetin in combination with maximum allowable levels of BHA and BHT should be tested to determine whether true synergism occurs and to assess the potential value of this treatment in extending potato flake shelf life. Favorable results would then justify consideration of quercetin availability, cost and FDA approval.

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